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XI

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MOLECULES OF GAS AND GRAINS OF DUST IN INTERSTELLAR SPACE*

BY C. S. BEALS

ALTHOUGH it has been known for many years that gases and dust grains are present in interstellar space it is only comparatively recently that their cosmic significance has been fully recognized. This sparsely distributed material, which was difficult to identify or to investigate in detail before the advent of powerful modern spectrographs, was originally regarded as an unimportant constituent of space as compared with the stars and other heavenly bodies. It has been considered in the past that the interstellar material consisted of atoms thrown off by the stars or that it represented the insignificant remains of the process of the formation of stars. While there is nothing qualitatively illogical about such ideas, the quantitative picture of the relative importance of stars to interstellar matter is now completely altered. Most astronomers now believe that the total mass of interstellar matter is greater than that of the stars and that the process of the condensation of stars may still be going on. This possibility, or as some would insist, this probability,[1] lends a heightened significance to all current investigation of interstellar matter. The fact that, according to some recent theories, even the planets find an eventual origin in the interstellar material is an additional reason why our Society members might take a special interest in this branch of astrophysics. It seems, therefore, to be an appropriate subject for an address on this occasion and I have chosen it partly for the reasons outlined above and partly because it has been for many years one of my own major scientific interests.

GASES IN INTERSTELLAR SPACE

(*a*) *Atomic Absorption Lines.* The first definite indication of the general distribution of gases in interstellar space was Hartmann's discovery[2] of stationary calcium lines in the spectrum of the star δ Orionis. This

*Presidential Address delivered at the Annual Meeting of the Royal Astronomical Society of Canada, January 18, 1952.

star, which is a single-lined spectroscopic binary of period 5.73 days and a velocity range of 170 km./sec., is scarcely an ideal one for such an observation because its calcium lines are extremely weak. However, they are strong enough to be detected by a skilled and careful observer and the velocity range of the binary is sufficiently great to leave no doubt of the peculiar behaviour of the interstellar lines which remain unchanged in position during the characteristic oscillations of the lines of the binary star.

Once the initial observation had been made there soon appeared a wealth of evidence pointing to the existence of absorption lines caused by gases in interstellar space. It was observed for example that many

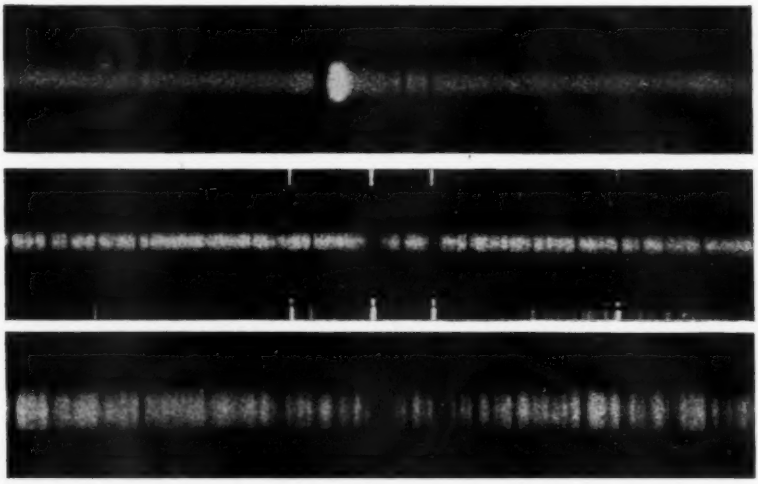

FIG. 1.—Sodium Lines in the Spectrum of P Cygni.

Top: spectrum of P. Cygni. The strong doublet is due to interstellar absorption by the sodium lines λλ 5890–5896. A faint component due to interstellar absorption may be seen to the left of each interstellar line. *Centre:* spectrum of α Ursae Majoris; *Bottom:* spectrum of α Scorpii.

early type stars with broad lines due to rapid rotation exhibited also calcium lines that were fine and narrow and therefore presumably caused by a source outside the star. In the spectra of a number of stars with high constant velocities the velocities of the calcium lines were low, close to the reflex of the solar motion, and thus attributable to absorption by material outside the star. The calcium lines in the spectra of O and B type stars were observed to increase in intensity with distance, as would be expected if they were of interstellar origin. In addition to calcium lines, fine and narrow lines due to the sodium doublets at λ 5893 and λ 3302 were discovered by Miss Heger,[3] and it was difficult or im-

possible in the case of the hotter stars to attribute such lines to the atmospheres of the stars. Finally, an examination of the spectra of distant novae, all of which exhibit violent and progressive changes in the forms and positions of the stellar lines, revealed the presence of sharp and narrow lines of calcium and sodium which remain unchanged in intensity and position as would be expected if they were of interstellar origin.[4]

The appearance of strong interstellar lines of sodium and calcium, to the exclusion of other atoms, might at first suggest that these atoms are more abundant than others in interstellar space, but it was quickly recognized that this was not the true explanation. Since, under the excitation conditions of interstellar space, practically all the atoms will be in the ground state, for an atom to show observable absorption it will be essential that the very intense "ultimate" lines due to transitions from the ground state should be in a region available to stellar spectroscopists. This would rule out hydrogen and others of the lighter atoms whose ultimate lines are in the inaccessible far ultra-violet regions. Sodium and singly ionized calcium are among the relatively few atoms which fulfil the necessary conditions and this accounts for their early observation as interstellar lines. Other atoms with ultimate lines in the region 3000 to 8000 angstroms are KI, CaI, TiII[5] and FeI[6] and a search revealed that interstellar lines caused by these atoms actually do appear. For ionized titanium it is interesting to record that although the ground state, ^4F, consists of four sub-levels, only lines arising from the lowest of these have been observed. This leads to the conclusion that under the low excitation conditions of interstellar space, sub-levels above the ground state are depopulated by forbidden transitions and are therefore incapable of giving rise to observable absorption. This observation later proved to be of considerable importance for the interpretation of molecular absorption in interstellar space.

(*b*) *Molecular Absorption.* The nature of the observed atomic absorption makes it possible to predict what might be expected for molecules. Since atomic energy levels of extremely low excitation potential are found to be unoccupied and incapable of giving rise to absorption it might logically be expected that most of the rotational levels in the normal state of the molecule would be similarly unoccupied. Under such conditions the complex, many-lined bands of laboratory or stellar spectra would be replaced by single lines or at most by two or three isolated narrow lines. This was indeed found to be the case and all the molecular absorptions so far attributed to interstellar gas consist of narrow lines in no way different except in intensity from the corresponding lines of atoms. Tables I and II show the atomic and molecular absorption lines that have been observed to date. It will be noted that for these two tables the atoms

involved are quite different, illustrating again the point already mentioned that abundance alone is not the sole criterion for the appearance of an interstellar line.

TABLE I

INTERSTELLAR LINES OF ATOMIC ORIGIN

Absorption Lines			Emission Lines		
Atom	λ	Multiplet	Atom	λ	Multiplet
NaI	3302.38	$3^2S - 4^2P^0$	H	4340.48	$2^2P^0 - 5^2D$
NaI	3302.98	$3^2S - 4^2P^0$	H	4861.34	$2^2P^0 - 4^2D$
NaI	5889.98	$3^2S - 3^2P^0$	H	6562.81	$2^2P^0 - 3^2D$
NaI	5895.94	$3^2S - 3^2P^0$	OII	3726.12	$a^4S^0 - a^2D^0$
KI	7664.88	$4^2S - 4^2P^0$	OII	3728.91	$a^4S^0 - a^2D^0$
KI	7698.98	$4^2S - 4^2P^0$	OIII	4958.91	$2p^2P - 2p^1D$
CaI	4226.74	$4^1S - 4^1P^0$	OIII	5006.84	$2p^2P - 2p^1D$
CaII	3933.68	$4^2S - 4^2P^0$	NII	6548.1	$2p^2P - 2p^1D$
CaII	3968.49	$4^2S - 4^2P^0$	NII	6583.6	$2p^2P - 2p^1D$
TiII	3072.97	$a^4F - z^4D^0$			
TiII	3229.18	$a^4F - z^4F^0$			
TiII	3241.97	$a^4F - z^4F^0$			
TiII	3383.78	$a^4F - z^4G^0$			
FeI	3719.95	$a^5D - z^5F^0$			
FeI	3859.92	$a^5D - z^5D^0$			

TABLE II

INTERSTELLAR ABSORPTION LINES OF MOLECULAR ORIGIN

Molecule	Line	Interstellar λ	Lab. λ
CH	R(1)	4300.34	4300.31
CH	$P_{Q12}(1)$	3890.25	3890.23
CH	$Q(1) + Q_{R12}(1)$	3886.44	3886.39
CH	$R_2(1)$	3878.81	3878.77
CN	P(1)	3875.77	3875.77
CN	R(0)	3874.62	3874.61
CN	R(1)	3874.02	3874.00
CH +	R(0)	4232.58	4232.57
CH +	R(0)	3957.72	3957.71
CH +	R(0)	3745.33	3745.30

(*c*) *Emission Lines in Interstellar Space.* Before leaving the subject of the identification of atoms and molecules in interstellar space, some mention should be made of the emission lines associated with diffuse nebulae as well as with regions of the sky where a casual inspection does not reveal any evidence of bright nebulosity. The Orion nebula is an excellent example of a diffuse mass of gas made luminous by hot stars in its immediate vicinity. It is well known that the spectrographic observation of the bright diffuse nebulae reveals emission lines due to H, He,

O, N, and other atoms in various stages of ionization. It is now believed that the Orion and other diffuse nebulae are simply condensations of a type of matter which is generally distributed throughout interstellar space.

Evidence that this is the case is found in observations of interstellar emission by Struve and Elvey at the McDonald Observatory.[7] For these observations they made use of a nebular spectrograph consisting of a Schmidt camera of focal ratio 1.0 used in conjunction with two prisms and a narrow plane mirror at a distance of 150 feet as a slit. With this equipment they were able to isolate regions of the sky of small angular extent and to investigate the presence or absence of emission lines. The programme produced some very interesting results and emission lines due to H, OII, NII, and OIII were observed in many parts of the sky not hitherto associated with bright nebulosity. The distribution of the emission regions indicated that they were associated with O type stars. They appear to exhibit stratification somewhat similar to that of the planetary nebulae, OIII appearing in the central regions while atoms of lower ionization potential such as H, OII, and NII extend to greater distances from the exciting stars and are sharply bounded on the outside.

These observations give strong confirmation to the idea that the relatively condensed diffuse nebulae are composed of the same material, that is more thinly distributed throughout the extent of the galaxy. If this is the case then the chemical constitution of the diffuse nebulae as revealed by the spectrograph is probably a good index of the kind of atoms existing throughout interstellar space and to the atoms of Tables I and II we may add a number of additional atoms, the most important of which is helium, which are characteristic of the nebulae. Since these are also the atoms which figure most prominently in the spectra of the early type stars we may safely go a step further and conclude that the material of interstellar space is the same as that of which the stars are composed. The absence of many atomic and molecular lines clearly visible in the spectra of the stars need not upset this conclusion since the condition of approximate thermodynamic equilibrium found in the atmospheres of the stars does not prevail in interstellar space. The evidence is now overwhelming that the stars, the planets, and the interstellar gas are all made of the same material and that this material comprises the familiar list of atoms found in our elementary chemistry books. While the atoms are the same, there are, of course, major differences in relative abundance. It is well known that the stars contain much more hydrogen and helium than the planets and this is almost certainly true also of interstellar space. It has been estimated that fully 90 per cent. of the interstellar gas consists of hydrogen and the major mass of the galaxy is thus composed of this element.

Dust Grains

In addition to the molecules of gas in interstellar space, there is also much solid material in a finely divided state. We used to speak of solid particles but the term "particle" has now been pretty well pre-empted for the various component parts of the atom. Some investigators have used the term "smoke" for the interstellar solid material but here the term is too closely associated with combustion to be entirely acceptable. The term dust grains now seems to be coming into common use and while it lacks something in euphony it is not seriously ambiguous in meaning. The following observational evidence points to the presence of dust grains of small size in interstellar space.

There are numerous areas of the sky where the distribution of the stars appears to thin out so rapidly as to demand the presence of obscuring material. It is impossible to attribute this obscuration to the presence of gas alone since ordinary gases are very poor absorbers except in the neighbourhood of their spectral lines. A few pounds of dust grains of suitable size, suitably distributed, are more effective in producing general absorption than many tons of gas and it is now believed that the dark markings in the sky are caused almost entirely by dust clouds.

In association with the bright diffuse galactic nebulae, not only stars but portions of the nebulae themselves appear to be obscured. Such obscuration is almost certainly due to the presence of dust grains and it is now generally accepted that all the diffuse nebulae consist of both dust and gas. In this connection it is interesting to record the contrast between the spectra of nebulae illuminated by hot (O or B) stars and those having only cool stars in their vicinity. The nebulae illuminated by hot stars have their main luminosity concentrated in emission lines which are excited by a process of ionization and recombination due to the absorption of ultra-violet starlight. Combined with the emission lines is a continuous spectrum but it is of low intensity relative to the emission lines. The nebulae associated with cool stars show a continuous spectrum only and an analysis of this spectrum shows that it is closely similar to that of the neighbouring stars. This is interpreted to mean that the nebular luminosity observed is simply that of the stars reflected from the dust grains with relatively little alteration.

Other evidence for such massive obscuration as would be caused by dust grains is found in the zone of avoidance of the Milky Way through which no extra-galactic objects such as globular clusters or spiral nebulae are visible and the presumably similar dark obscuring band associated with certain spiral nebulae which are seen edge on. It should perhaps again be emphasized that the amount of gas required to produce such obscuration is hundreds of times greater than the best estimates of the

density of the galaxy would permit, so that there is no choice but to attribute the dark bands to the presence of dust grains.

In addition to the presence of obvious obscuring clouds and such conspicuous phenomena as the zone of avoidance in the galaxy and the dark bands in spiral nebulae, there have also been observed departures from the inverse square law of brightness for stars whose distances and intrinsic luminosities are known with reasonable certainty. Quantitative studies of these effects lead to a general absorption coefficient in the galaxy of about 0.8 stellar magnitudes per thousand parsecs. This means that a star situated at a thousand parsecs from the earth has its light reduced to less than half its original brightness by absorption. This indicates that the absorbing dust grains not only appear in clouds giving rise to massive absorption but that they are also generally distributed throughout the galaxy in a manner similar to that of the interstellar gas.

While the evidence for general absorption just outlined has left little doubt in the minds of astronomers of the existence of dust grains in interstellar space, an additional absorption phenomenon has been observed which gives some insight into the sizes of the grains. It has been known for many years that numerous early type stars of classes B and O whose normal colour should be blue or blue-white are actually seen to be yellow or reddish when observed photographically or photometrically with a telescope. With the aid of powerful reflectors such as those at Victoria or Toronto this effect can be quite easily observed visually for some of the early type stars in Perseus and Cygnus. Quantitative spectrophotometric studies have demonstrated even more convincingly that distant stars are reddened by absorption in interstellar space. Measures of the spectra of such stars have indicated a law of absorption inversely proportioned to wave-length. This means that, for example, light of wave-length 4000 A. suffers approximately twice the absorption of that at 8000 A. This relationship makes possible an estimate of the average sizes of the particles producing the absorption. Small particles of the order of size of gas molecules give rise to so-called Rayleigh scattering which is inversely proportioned to the fourth power of the wave-length of the light absorbed whereas if the particles are sufficiently large they absorb alike the light of all wave-lengths. For particles of intermediate size an absorption law in between the two extremes will hold. Calculation shows that for the observed λ^{-1} law the average sizes of the particles must be in the neighbourhood of 10^{-5} cm.

It is not to be supposed, of course, that all the dust grains are of the same size and it is probable that all diameters are represented from gas molecules up to gross rocks or bodies of asteroid or planetary dimensions. It was, in fact, formerly believed that many of the so-called sporadic

meteors came from interstellar space and this was supposed to give some idea of the upper limits of size of the interstellar grains. However, recent observations of meteors at Ottawa,[8,9] Harvard,[10] and Manchester[11] have indicated that all or practically all of the observed meteors are associated with the solar system, and it is not certain that any of them are from outside space. It is probable, therefore, that bodies of meteoric size are extremely rare and that the great bulk of the dust grains are of microscopic dimensions.

Unidentified Interstellar Lines

While the atomic and molecular interstellar lines give positive evidence of the chemical identification of at least some of the gases of interstellar space, similar information is lacking for the dust grains. It is logical to suppose that they are composed of such common elements and compounds as exist as solids at the temperature of interstellar space. Since such solids are very numerous this does not tell us a great deal and any observations which could shed further light on this point would be of the greatest value and significance.

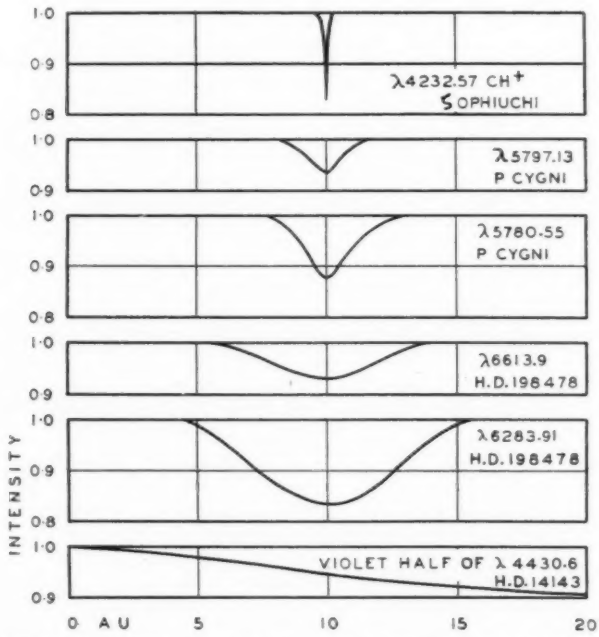

Fig. 2.—Diffuse lines of unknown origin compared with molecular line due to CH^+.

In this connection it may be pointed out that there are a number of unidentified absorption features in the spectra of stars which might conceivably have their origin in absorption by dust grains. These spectral features are very different from the sharp narrow absorption lines which have been identified as due to gases in interstellar space. They are broad and diffuse and difficult to detect except on microphotometer tracings of stellar spectra. The narrowest is more than 10 angstroms wide—while the widest has a breadth of 60 angstroms. The wave-lengths of these features, which were discovered by Merrill and his collaborators,[12,13] are given in Table III. No reasonable doubt exists of their interstellar char-

TABLE III

UNIDENTIFIED INTERSTELLAR LINES

Diffuse Lines		Sharp Lines	
	Int.		Int.
4430.6*	10	3579.04‡	0
4760†		3934.3§	0
5780.55	3		
5797.13	1		
6202.99	1		
6269.99	1		
6283.91	6		
6613.9	2		

*This indication of intensity reflects the equivalent width of this line. The actual existence of the line is frequently difficult to detect because of its great width and small central depth.
†A broad feature tentatively identified by Merrill as an interstellar line. (Private communication).
‡May be due to 3.0 band of CH^+ system.
§May be due to NaH (*Ap. J.*, vol. 93, p. 11, 1941).

acter. They exhibit a stationary behaviour when observed in the spectra of binary stars with large velocity amplitudes and they have been shown to increase in intensity with distance in a manner consistent with an interstellar origin. Various attempts have been made to associate them with the band spectra of gaseous molecules but evidence has accumulated that gases in interstellar space whether due to atoms or molecules cannot give rise to broad features of this kind. The only alternative then appears to be the dust grains, and if some of these grains are in the form of transparent or semi-transparent crystals, it is possible that they might give rise to the observed absorption. Such a proposed explanation is not much favoured by theoretical investigators, who feel that it is not applicable to the very small particles mainly responsible for the interstellar absorption, but so far no alternative has been suggested. Many absorption lines or bands of solid substances in the laboratory have been

observed to be of the same general character but none has been found to coincide in wave-length with the interstellar features. Their origin therefore remains a major unsolved problem of astrophysics and one whose solution constitutes a challenge both to the theoretical investigator and to the laboratory spectroscopist.

Clouds of Dust and Gas and Their Motions in Interstellar Space

Photographs of the sky showing dark patches of obscuring matter indicate that the dust grains are not uniformly distributed in space and that there is a tendency for them to occur in clouds. Certain patches of bright luminosity, such as those associated with the Pleiades, whose spectra are similar to those of neighbouring stars, also point to the presence of clouds of finely divided solid materials in interstellar space. If the dust grains tend to congregate into clouds it would seem reasonable to expect that there might be clouds of gas also, and two quite separate types of observations confirm this view. First, the bright diffuse galactic nebulae which are associated with hot stars and which exhibit strong emission lines in their spectra may safely be regarded as condensations of the interstellar gas. As has already been mentioned, some of these nebulae show indications of continuous spectrum as well as dark markings obscuring parts of the bright nebulosity. It is probable, therefore, that all of these clouds consist of both dust *and* gas and we will likely be not far wrong in assuming that a condensation of dust grains is normally associated with an accompanying cloud of gas.

A second type of observation which indicates the presence of gaseous clouds is found in the complex character of many interstellar absorption

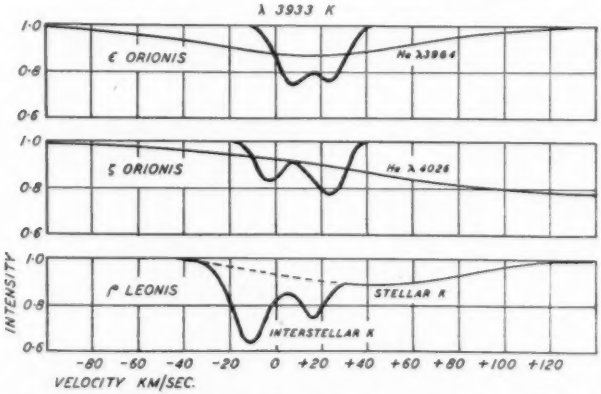

Fig. 3.—Complex lines of interstellar calcium compared with stellar lines.

lines. When observed with spectrographs of small dispersion (of the order of 30 A./mm.), interstellar lines appear very fine and narrow. If the dispersion is increased to the order of 4 or 5 A./mm., they appear less sharp, and lines which formerly appeared single are sometimes seen to be double or multiple. Such multiple lines were first seen at Victoria where the stars ρ Leonis, ϵ Orionis, and ζ Orionis were observed to show double interstellar lines.[14] The double character was shared by both calcium and sodium and there appeared no doubt but that it arose in the interstellar medium. Later Adams,[15] at Mount Wilson, using still higher dispersion, showed that a majority of the interstellar lines were of multiple character. The obvious and generally accepted explanation of these multiple lines is that they are due to discrete clouds of interstellar gas having relative velocities large enough to form separate absorption lines.* Some of the lines due to distant stars have as many as six separate components with extreme relative velocities as great as 60 km./sec. This suggests that the interstellar gas clouds are similar to the stars in that each has its own peculiar random motion in addition to such motions as are associated with the galaxy as a whole.

That the galaxy as a whole rotates about its centre with a period of about 250 million years has been known since the pioneer theoretical studies of Oort[16] and their observational verification by Plaskett and Pearce[17] approximately two decades ago. This general motion of rotation was revealed through studies of the radial velocities of stars. It was shown that stars nearer the galactic centre rotated about it more rapidly than those further away and in this the motion has some points of similarity to that of the planets in the solar system. Quantitatively, the motions due to galactic rotation of stars relative to the sun are given by the well-known equation

$$v = r\,A \sin 2(l - l_0) \cos^2 b$$

Here v is the radial velocity of the star with the solar motion removed, r is the distance of the star, A is a constant depending on the character of the galactic motion, l is the galactic longitude of the star, l_0 is the longitude of the galactic centre and b is the galactic latitude.

Studies of the velocities of interstellar lines indicated that the interstellar material also partook of the motion of rotation of the galaxy. Analysis of these velocities on the basis of the above equation indicated that they were on the average exactly half those of the stars and this leads to the conclusion that, statistically at least, the clouds of interstellar gas are uniformly distributed throughout the extent of the galaxy.

*Routly and Spitzer (*Ap. J.*, vol. 115, p. 227, 1952) have presented evidence that the proportion of sodium to calcium is much less than the average for some of the high velocity clouds.

Before leaving the subject of the motions of interstellar clouds, it may be of interest to consider some of the consequences of collisions between clouds. This is a subject which has been investigated theoretically by Oort[18] and his collaborators in Holland, who have pointed out that since the interstellar clouds are of large extent and have high peculiar velocities, of the order of several tens of kilometres per second, it follows that sooner or later there will be collisions between clouds. For relative velocities of the order of 40 km./sec. it has been shown that the density and temperature of the compressed region where the clouds meet will rise to high values relative to the remaining part of the cloud. It is probable that the rise in temperature will be sufficient for hydrogen to be excited and ionized by collisions and the gas will thus become luminous. In the case where one cloud is of considerably lower density than the other it is the thin cloud which will become luminous. It is possible that certain bright nebulae which are not obviously excited by nearby stars may owe their nebulosity to this cause. Oort has suggested that the nebulosity near ζ Orionis and the North American Nebula may be made luminous by the collision mechanism.

In this same connection it is interesting to point out that the material thrown off by a nova may similarly be decelerated and excited to nebulosity by collisions with interstellar matter. For an ordinary nova it would clearly be difficult to distinguish between the luminosity stimulated by collisions and that due to light of the central star. One interesting case of an expanding shell where this difficulty is minimized may owe its luminosity largely to the collision mechanism. The symmetrical structure of the two parts of the Network Nebula in Cygnus as well as their curvature, which indicates that they are parts of a circle of large diameter, make it highly probable that they are the remnants of a shell thrown off by a star, presumably a nova. The nova has long since faded and since no star has been found that is capable of exciting the observed nebulosity, the suggestion has been made by Oort that the necessary energy is provided by collisions of the moving clouds with the interstellar matter which finds itself in their paths. While this is by no means proven it is an exceedingly interesting hypothesis and if the deceleration of the gas clouds could be measured an important new approach to the properties of interstellar matter would be possible.

Another consequence of collisions between interstellar clouds will be the vaporization of many of the dust grains. Since these encounters will ordinarily occur at relative velocities of some tens of kilometres per second, it can easily be shown that the heat generated by a collision between two dust grains will be sufficient to vaporize them. This process may well be an important factor in maintaining equilibrium between gas and dust grains in interstellar space, since without some means of trans-

forming the solid grains into gas the opposite process might go on so rapidly as to make it impossible for appreciable amounts of gas to exist.

The Polarization of Light by the Interstellar Medium

Perhaps the most significant development of recent years in the field of interstellar research has been the discovery by Hiltner[19] and Hall[20] that the light of many of the distant early type stars is polarized, sometimes by a proportion as great as 12 per cent. Since in a spherically symmetrical source such as a star there is no reason to expect polarization unless part of the stellar surface is obscured by an eclipse, it is logical to suppose that the polarization is a consequence of the properties of interstellar material. An analysis of the observations lends considerable support to this view. It has been shown, for example, that the more distant stars which are strongly reddened by absorption are also the most strongly polarized. It has further been shown that the planes of polarization observed for different stars are not distributed at random but show correlations with one another which suggest that very large volumes of space have similar polarization properties. Finally, polarization is, in general, correlated with the galactic plane in such a way that the electric vector of the polarized light is in the plane of the galaxy. This would suggest that the polarizing medium is an assemblage of elongated dust grains in space which are in some way aligned in a manner capable of giving rise to polarization effects. Up to the present the only agency which is considered to be capable of producing such an alignment is a galactic magnetic field presumably associated in some way with the motion of rotation of the galaxy.

There have been two main suggestions put forward as to the types of particles which might be capable of taking up a definite alignment in a magnetic field. One suggestion by Spitzer and Tukey[21] postulates the existence of long needle shaped grains of ferromagnetic material each of which is a tiny magnet. It is not necessary to suppose that all the interstellar grains are of this character since a relatively small proportion of them might be expected to produce the observed effects. An alternative proposal put forward by Davis and Greenstein[22] is based on the assumption that the polarizing units are elongated paramagnetic dust grains rotating about their shorter axes. Here the physical action is somewhat more complex and depends on what is called paramagnetic absorption, the result of which is to align the spinning grain with its axis of rotation parallel to the magnetic field. Such a mechanism will produce a complex of grains capable of polarization but of different character from that proposed by Spitzer and Tukey.

Neither observation nor theory has yet advanced far enough to make it possible to decide between these alternatives. Nor is the source or

direction of the supposed magnetic field as yet known with any degree of certainty. Enough has been accomplished, however, to show that a remarkable new field of astrophysics has been opened up and one which promises important new advances in our knowledge of the nature of the galaxy and of the material from which we believe the stars and the planets to have come.

In addition to the developments outlined above, which represent some of the most interesting recent advances in the study of interstellar matter, I should like to touch briefly on a few additional points though time does not permit any detailed presentation.

The subject of the ionization and density of interstellar matter has been treated rather thoroughly in earlier papers and reviews and the position has not changed greatly during the past few years. The values of density derived from the motions of the galaxy by Eddington[23] and Oort[24] and those derived on the basis of hydrogen emission line intensities by Dunham[25] and Struve[26,27] seem now to be in fair agreement and a value of the order of 5×10^{-24} g./cc. should fairly represent the present day position.[28,29] The temperature of interstellar space as defined by the motions of atoms and electrons is believed to be of the order of 10,000° to 15,000°.

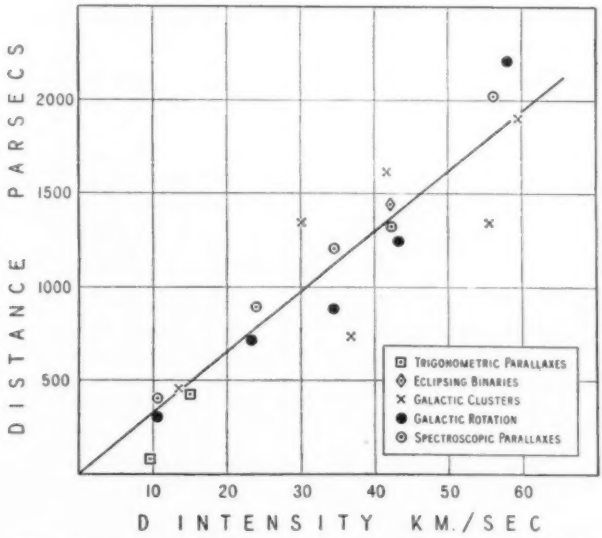

FIG. 4—The Relation between Distance and Interstellar Line Intensity for Sodium. The values of intensity are given as equivalent widths in km./sec. and represent the mean $(D_1 + D_2)/2$.

A new determination of the relationship between interstellar line intensity and distance has been made by Beals and Oke. It is probable that the scatter in these diagrams fairly represents the uncertainty in the average relationship between intensity and distance. It seems unlikely that further work will substantially alter the overall relationship and future advances are more likely to take the form of evaluating the absorbing properties of localized regions of the galaxy.

Some interesting work in the dynamics of the interstellar medium by Spitzer[30] has indicated that the effect of radiation pressure is greater for the dust grains than for the gas and that in some instances it may have an appreciable effect on cloud motions. Stebbins and Whitford have recently put forward the interesting suggestion that part of the reddening of distant galaxies may be due to absorbing material in interstellar space. This cannot yet be regarded as confirmed and it may be that all the reddening will eventually be found due to other causes.[31] The existence and nature of interstellar material in other galactic systems is a subject which has already received some attention and is certain to be of increasing interest as improved facilities make the necessary observations possible. These are but a few of the many avenues of approach to the complex physical problems presented by interstellar matter. In a field so vast we cannot forecast the direction that future investigations will take but in view of the inspiring developments of the past few years we can look forward with confidence to further triumphs of the scientific method in exploring this aspect of the great universe.

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MINUTES OF THE ANNUAL MEETING OF THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

THE combined 62nd Annual Meeting and the Annual At-Home was held at 8:00 p.m. on Friday, January 18, 1952, in the McLennan Physics Laboratory, University of Toronto; the President, Dr. C. S. Beals, in the chair.

Moved by Mr. E. J. A. Kennedy and Mr. J. H. Horning that minutes of the annual meeting and At-Home, held respectively on January 12 and 19, 1951, having been published in the JOURNAL, be adopted as read. Carried.

Copies of the National Secretary's report and National Treasurer's statement having been distributed to members present, these officers summarized them briefly. Mr. Kennedy also announced the award of the Chant Medal for 1951 to Mr. DeLisle Garneau of Montreal. As Mr. Garneau was unable to be present to receive it, the medal was to be forwarded to Montreal and the award made at a meeting of the Centre français.

Moved by Mr. Kennedy and Mr. A. R. Clute, K.C., that the National Secretary's report be received and be published in the JOURNAL. Carried.

Mr. Horning pointed out that increasing expenses had nearly obliterated the help obtained in recent years since the annual dues were increased to three dollars, and announced that efforts were being made to produce the JOURNAL more economically and to reduce other expenses where possible. He moved, seconded by Mr. Kennedy, that the financial report be received and be published. Carried.

The Scrutineers, Messrs. F. L. Troyer and W. R. Sherrick, reported a majority of the 329 ballots returned by mail were in favour of the election of the Officers and Council as listed thereon, but noted that 20 members of the Winnipeg Centre desired a different representative on the National Council than the one earlier submitted to the Nominating Committee and printed on the ballot. The meeting decided that as a majority of all members had voted in favour of the listed representative no action could be taken at this time and left the matter in the hands of Council pending further correspondence with the Winnipeg Centre. Dr. Beals then declared the Officers and Council for 1952 elected as printed on the ballot.

Dr. J. F. Heard announced that the Frank S. Hogg Memorial Scholarship Fund had reached three-quarters of its $10,000 objective. Dr. Beals said this fund would "in years to come recall to young students in the University of Toronto the name of the former head of the Department of Astronomy who was so well liked by his students and so highly regarded by his professional colleagues around the world."

Moved by Mr. Horning and Mr. Troyer that the National Council investigate the possibility and be empowered to take appropriate action in making a contribution to the Frank S. Hogg Scholarship Fund from the Society's "Southam Press Fund." Carried.

Dr. Heard, who as First Vice-President took the chair to introduce Dr. Beals, noted that the President had been elected a Fellow of the Royal Society (London) since the Society's last meeting and said the honour was one which comes to only a few Canadian scientists. He added that he was sure the honour was in part, at least, due to Dr. Beals' outstanding work on the subject of interstellar matter.

Dr. Beals then delivered the Presidential Address on the topic, "Molecules of Gas and Grains of Dust in Interstellar Space." (This paper appears elsewhere in this JOURNAL.)

Following this address, the meeting adjourned to the upstairs Library where a Social Hour was held and refreshments enjoyed by the members and guests.

FREDERIC L. TROYER, *Recorder.*

REPORT OF THE NATIONAL SECRETARY

EACH of the fourteen Centres of the Society sends in to headquarters a report of its progress during the year. These reports are printed in the March JOURNAL each year. A study of these documents will give the members an adequate picture of the varied activities of the Society in promoting the interest of the public in the very worthwhile and entrancing subject of astronomy. It will also show the important part the Society plays in the cultural development of Canada.

This present report covers only the highlights of the transactions of the National Council. They met four times during 1951.

In the year previous, it will be remembered, a very exhaustive brief was prepared to present to the Royal Commission on the Cultural Development of the Arts and Sciences. The brief reviewed the history and accomplishments of the Society, emphasizing the voluntary nature of its efforts in promoting the science of astronomy, and the need for increased government assistance. This was to be presented by Mr. Andrew Thomson, Chairman of the Committee, but because of his illness, Dr. C. S. Beals appeared before the Commission. The Commission's report has been published with some favourable mention of the encouragement which our Society has given to cultural development of the sciences. As yet, no practical results have materialized but the Committee is still hopeful.

The Council has been greatly interested in the investigation by Dr. V. B. Meen and Mr. Fred Chubb of the phenomenon which is now known

as the "Chubb Crater." At the last Annual Meeting, a resolution was passed as follows:

That this Society go on record as urging the Canadian Government to designate the area involving the recently explored crater in Ungava as a National Park, or to take other appropriate steps to preserve this crater as an object of scientific interest and that the National Council be asked to take the necessary steps for action.

Your Secretary has placed this resolution before the proper department in Ottawa, and also the Department of Lands and Forests of the Province of Quebec. A reply was received from the Deputy Minister who has taken steps to place before the Executive Council the proposal to set aside the area as a scientific reserve. We have been assured that the Council is favourable and the necessary steps are now being taken.

It is interesting to note that Dr. Meen, under the sponsorship of the National Geographic Society, made a second trip to Ungava this past summer. His report, which is printed in the January number of the *National Geographic Magazine*, would indicate that he is convinced that this great depression was caused by none other than a very large meteorite. In area, it is much larger than the crater in Arizona.

The award of the Chant Medal for the year goes to Mr. DeLisle Garneau. Mr. Garneau has carried forward some very important observational work in Montreal Centre. Several articles by him have appeared in the JOURNAL from time to time, showing him to be a very careful observer. He has made very definite contributions to our knowledge of the heavens.

The Council is very anxious to see the interest in this important award extended. It is meant only for amateurs, as a stimulus to independent observation. In addition to the great pleasure the amateur receives from close acquaintance with the splendours of the heavens, he is urged to turn to the serious side of observing, in which field he can add much to our knowledge of the science. Some have already brought fame to themselves by very important discoveries.

The losses of the Toronto Centre by death have been heavier in 1951 than in any other similar period we can remember, starting with Dr. Frank Hogg, whose death occurred on the first day of January, and whose obituary was published in the January JOURNAL. Mr. H. W. Barker, who passed away on January 29th, had been a member of Council and an officer at different times during the past thirty years. Prof. Alfred Tennyson DeLury, a Past President and a life member since 1893, and Mr. Arthur K. Knight, an active member, have also passed on.

A newly organized Halifax Astronomical Society is interested in becoming affiliated with our Society as a Centre. This will be of great interest to the Council as it has long been desirous of having a Centre on the east coast. Up to the present, we have had no Centre farther east than Quebec City. Our President, Dr. Beals, while in Halifax recently, had a visit with

some of the officers, with the result that we may expect them to join us in a year's time.

There was a discussion by the Council of a proposal to change the format and appearance of the JOURNAL. Some minor changes in the page size, stitching, and method of reproduction of illustrations was approved. The major changes suggested were held over for further discussion.

We are grateful to the various Centres for their co-operation in sending in reports promptly.

E. J. A. KENNEDY, *National Secretary.*

CHANT MEDAL AWARD, 1951

The award of the Chant Medal for the year 1951 goes to DeLisle Garneau, president of the Centre français de Montréal and second vice-president of the national society. Mr. Garneau's interest in astronomy has extended over thirty years and in 1936 he began systematic observations with a four-inch telescope. His observations have covered the fields of sun-spots, planets, comets, variable stars, eclipses, and meteors. He has done much to interest people in astronomy, and is well known in the province of Quebec through his articles printed in a number of publications in Montreal and Quebec; for five years he has been writing a weekly column in the Montreal newspaper, *Le Devoir*. In 1941 Mr. Garneau built a small observatory in the rear of his home. In this building is housed the Montreal Centre's six-inch reflecting telescope. Since then his observatory has been a meeting place for observing groups every Saturday night.

REPORT OF THE LIBRARIAN

DURING the year 1951, periodicals were sent in exchange to

Canada and the Empire	37
U.S.A.	46
Other Countries	44
	127

The number of books lent from the shelves during 1951 was 45. We received regularly, chiefly from the Empire and America in exchange for our own publications, 127 publications of other societies and institutions of learning. These are available in the reading room where members may look them over and any required may be taken out on loan for limited periods.

The film, "Solar Prominences" (16 mm.), has been much in demand by nearly all the Centres. We hope other satisfactory films will soon be available.

D. W. BEST, *Librarian.*

REPORTS OF SECRETARIES OF CENTRES

Toronto Centre

Eleven regular meetings were held during the year, including five public lectures and five Members' Nights at the University of Toronto, and the annual Members' Night at the David Dunlap Observatory. Four Star Nights were arranged during the summer on the University of Toronto campus but one was cancelled by rain. The Council met once and the Executive on several occasions.

The Centre again held a telescope display at the Canadian National Exhibition, several telescopes being set up for public use on each of the ten clear or partly clear evenings. More than 5,000 Exhibition visitors saw through the telescopes and each was given a copy of the Centre's *Sky Facts* folder. We are again grateful to the *Toronto Star* whose advertising on the back page made possible the printing of the sixth annual issue of this leaflet. A public address system loaned by Mr. W. R. Sherrick, assisted greatly in explaining to visitors the objects being viewed and in informing them of the Society's activities. Many members assisted in operating the telescopes and in guiding the queues, some of them being on hand nearly every evening.

Membership in the Centre stands at 345 including 54 new members elected during the year. We regret that the names of four prominent members have been removed by death from our rolls. They are: Dr. Frank Scott Hogg, director of the David Dunlap Observatory; Mr. Herbert Whitehead Barker, past president of the Centre and Recorder of the National Council; Professor Alfred Tennyson DeLury, dean emeritus of arts in the University of Toronto, a past president of the Society and a Life Member since 1893, and Mr. Arthur R. Knight, an active amateur.

Our Telescope Makers Group continues to expand and held meetings about every second week during the year. Members have completed more than 20 telescopes and a like number are in progress. Several of the instruments were in operation at our Summer Star Nights and at the Exhibition display. The three-inch Dale Telescope was in almost constant circulation on loan to members when it was not needed for the Centre's public observation gatherings.

Subjects and speakers at meetings were as follows:

February 6—Gerald M. Clemence, U.S. Naval Observatory: "The Measure of Time."
February 20—Members' Night. Programme of astronomical films.
March 6—H. C. Van de Hulst, Leiden, The Netherlands: "Radio from Beyond the Earth."
March 20—Members' Night. F. Keith Dalton: "Those Mysterious Meteorites."
April 3—T. F. McIlwraith: "Star Lore of the North American Indians."
April 17—Members' Night. Question Box and "Variety" programme.

May 14, June 12, and July 10—"Star Nights" on University Campus.
October 9—Annual Members' Night at the David Dunlap Observatory, Richmond Hill.
October 30—H. E. Duckworth, McMaster University: "Weighing Atoms—The Precise Measurement of Atomic Masses."
November 13—Members' Night: "What Amateurs Can Do to Aid Astronomical Progress."
November 27—Helen Sawyer Hogg: "Marvels of the Milky Way."
December 11—Member's Night. Film programme. Followed by the Annual Business Meeting of the Centre.

JOHN GALT, *Secretary.*

HAMILTON CENTRE

During the year 1951, eight regular meetings were held at McMaster University, two Field Nights, and two Council meetings to discuss business of the Centre. Membership stands at 64, including three life members.

January 4—A. E. Johns, Ph.D.: Planetarium Demonstration. W. J. McCallion, M.A.: "The Key to the Door."
February 1—T. M. Norton: "Evidences of the Rotation of the Earth." L. G. Reeds, M.A.: "The Earth, Past and Present."
March 1—O. J. Paton: "Evidences of the Revolution of the Earth." A. E. Johns, Ph.D.: "The Sun."
April 5—W. J. McCallion, M.A.: Planetarium Demonstration. Martin W. Johns, Ph.D.: "Planetary Systems."
May 3—G. E. Campbell, M.A.: "Slight Motions of the Earth." Ralph E. Williamson, Ph.D., David Dunlap Observatory: "Observational Techniques at the Time of Tycho Brahe."
September 7 and 8—Field Nights at McMaster University.
October 4—Presentation of the Truman Donald Norton Memorial Book Collection. H. E. Duckworth, B.Sc., Ph.D.: "Precise Measurement of Atomic Masses."
November 1—A. E. Johns, Ph.D.: "The Observer's Handbook." J. F. Heard, Ph.D., David Dunlap Observatory: "Modern Air Navigation."
December 6—J. H. Sled, Phm.B.: "Claudius Ptolemy." F. H. Gulbis, M.Sc.: "Cosmic Rays."

GEORGE MURCHIE, *Secretary.*

WINNIPEG CENTRE

In the course of the year six regular meetings were held, and we were fortunate in having an excellent Observation Night in May, the first since 1949.

The Society's plans for an Observatory have not as yet crystallized, but we expect within the very near future to have comprehensive plans by qualified architects presented to us on a scale suitable for the city of Winnipeg.

The topics dealt with at the regular meetings were as follows:

January 10—Four Films on "Nautical Astronomy," etc., courtesy of Air-Commodore M. Costello, R.C.A.F., Winnipeg.

February 14—Films: "Some Spring Time in Holland" and "Solar Prominences."
March 14—Film: "The Story of Palomar," by the California Institute of Technology.
May 9—Observation Night at the home of D. V. Pennock, 115 Hertford Boulevard, Tuxedo.
November 14—V. C. Jones: "The Development of Palomar."
December 12—Film: "Meet the Ducks," courtesy of Ducks Unlimited.

In all, the Society enjoyed a successful year and it is expected that the ensuing year will provide even more interesting and diversified topics for the membership.

A. J. VINCENT, *Secretary.*

VICTORIA CENTRE

Although 1951 was a year in which the Victoria Centre has lost members, it has not been an inactive one. Under the capable guidance of our president, Mrs. J. R. Noble, we held six regular meetings as well as our annual summer course. Our April meeting was in the form of a debate given by four of our members which was something a little different and which the members seemed to enjoy.

Our summer course went well over expectations this year with 185 persons attending so that a profit of $93.00 was realized. The president and Dr. Anne Underhill as acting secretary are to be congratulated on their splendid work.

Mrs. Noble, almost unassisted, did a wonderful job in arranging for the Astronomical League Convention held in July.

Likely due to high costs and our raise in dues we have lost some 51 regular members during the year so now have a total of 74 fully paid up members (including three junior members). A drive for new members seems imminent.

JOHN L. D. JERVIS, *Secretary-Treasurer.*

MONTREAL CENTRE

The past year has been a very active and successful one. In addition to observation and telescope-making activities, the Centre held thirteen general meetings with an average attendance of seventy-eight. Guest speakers included A. E. Covington, National Research Council; A. Vibert Douglas, Queen's University; D. A. Keys, National Research Council; Mrs. Margaret Mayall, Harvard College Observatory; Pierre Demers, University of Montreal.

An introductory series, entitled "A Picture of the Universe," was presented by our own members. There was also a symposium of three talks by members. The closing meeting of the season was a social with a photo quiz.

A feature of the meetings was a series of five-minute talks on the OBSERVER'S HANDBOOK, designed to make the HANDBOOK more useful to the members.

The following are some of the more important activities and items of interest during the past year. Mr. A. B. Whipple presented the Centre with an excellent six-inch reflecting telescope (in memory of Mrs. Whipple), which has been named the Gladys Whipple Telescope. Great interest has arisen regarding the Chubb Crater in Ungava. A resolution requesting the Provincial Government to set aside this phenomenon as public domain was passed by the Centre and sent to Quebec. The Council has established and set aside a separate fund known as the Observatory Fund in the hope and expectation that in time we may be able to finance the building of our own observatory. At the Tenth Anniversary meeting of the Centre de Québec held in Quebec City, the Montreal Centre was represented by the President, Miss I. K. Williamson and the Director of Observations, Mr. F. DeKinder. The Centre has become affiliated with the Greater Montreal Film Council which helps to further the distribution of suitable moving picture films.

HENRY F. HALL, *Secretary.*

REPORT OF THE DIRECTOR OF OBSERVATIONS

Soon after the last Annual Meeting, the Observation Committee met and the different activities were segregated into sub-committees and each put under the chairmanship and responsibility of one member. This has proved to be a very successful arrangement.

Sub-Committee 1—Variable star observers under Delisle Garneau. Eleven observations of variable stars were made and sent to the A.A.V.S.O.

Sub-Committee 2—Occultation observers under Wm. Birtles. Four occultations were completely recorded and sent to Mrs. H. Beardsley, Springfield, Vt. Fourteen unsuccessful attempts were made.

Sub-Committee 3—Telescopic observations of sun-spots have been made by three members. Altogether 864 groups have been recorded in 161 observations and sent to the Solar Division of the A.A.V.S.O.

Sub-Committee 4—Naked-eye sun-spot observers under Mrs. J. Wright, resulting in 230 observations which were sent to the Solar Division of the A.A.V.S.O.

Sub-Committee 5—Planetary observations under Brian Cockhill. Sixty-four observations of the magnitude of Uranus were made and sent to Walter Haas of New Mexico.

Sub-Committee 6—Lunar observations under Alec McLennan.

Sub-Committee 7—Observations of the aurora borealis under Mrs. D. Zorgo. Reports of 49 aurorae in 92 individual observations were sent to C. W. Gartlein, Cornell University.

Sub-Committees 8 and 9—Meteor showers and eclipses under Miss Isabel Williamson. The Perseid shower was observed on August 10–11 from 10.30 p.m. to 4.00 a.m. and 173 meteors were recorded.

Sub-Committee 10—Observation of sporadic meteors under E. E. Bridgen. Fifteen reports were received, of which six concerned the fireball of November 2, 1950. The reports of meteors were sent to P. M. Millman, Ottawa.

Sub-Committee 11—Nova search and comet observations under Thomas Noseworthy. Some 60 reports, containing 155 observations, were received and forwarded to Mrs. Margaret Mayall, Harvard College Observatory.

Sub-Committee 12—Telescope makers under Robert Venor. During the winter a regular course in telescope making was conducted. Six telescopes were completed. The Observation Committee wishes to express its gratitude to Mr. and Mrs. Eugene Charters who have generously given space in their house to this group.

Sub-Committee 13—Migratory bird observers under Geo. Harper Hall. Two observers have recorded birds in flight while observing the sun or moon. These reports are being sent to the Solar Division of the A.A.V.S.O.

Sub-Committee 14—The Asteroid Club for the younger members under Mrs. F. Hall.

Sub-Committee 15—The Messier Club under Paul Scott. The object of this section is for members to personally seek out each of the 100 nebulae and clusters in Messier's catalogue. This trains members in accurate instrument observation. To Tom Noseworthy belongs the honour of being the first member to complete this feat. Two other members have more than 80 Messiers to their credit, five have between 50 and 80, five have between 25 and 50, and 21 have found between one and 25 of the objects.

The Observation Committee has also held observation meetings at the observatory every Saturday night without interruption. Two Star Nights were held: one at Ste. Anne de Bellevue for the students of Macdonald College when the weather was cloudy. The other was at Westmount Park where 25 telescopes were set up; some 2,000 persons attended. Two films and a series of slides were shown and explained by John Duffy and Wm. Birtles. Question and answer periods were conducted by Dean Henry F. Hall.

Through the efforts of the members of the Observation Committee the Montreal Centre is being talked about in widely separated places. It was singled out in the Massey Report as an example of what laymen can do in the way of valuable use of leisure.

FRANK J. DEKINDER, *Director of Observations.*

REPORT OF LIBRARIAN, MONTREAL CENTRE

While the circulation of books was somewhat lower than usual, this was more than offset by a phenomenal increase in that of periodicals, particularly those pertaining to observational astronomy. Gifts of books and slides to the Centre were most generous; the current year being exceptional in the number of slides donated. Additions to the library during the year were:

BY PURCHASE

Photography in Astronomy: Selwyn
A Manual of Celestial Photography: King
Stellar Evolution: Struve
Making Your Own Telescope (copy 2): Thompson
The Stars in Our Heavens: Lum
Astronomy of Stellar Energy and Decay: Johnson

PRESENTED TO THE LIBRARY

The Nature of the Universe: Hoyle
Physical Optics: Wood

Essentials of Astronomy (copy 2): Duncan
The Realm of the Nebulae: Hubble
The Story of the Heavens: Ball
The Magic Universe: Bonner
Astronomy: Baker
British Ephemeris and Nautical Almanac
An Introduction to Electronics: Hudson
Some Firsts in Astronomical Photography: Hoffleit
Preferred Spellings and Pronunciations

BINDING AND REPAIRS

Men, Mirrors and Stars
Galaxies (copy 1)
R.A.S.C. Journal 1950
Palomar Pictorial (copies 1, 2)
Amateur Telescope Making (copy 3)
Binders for *Sky and Telescope* (2)
Preferred Spellings and Pronunciations
Some Firsts in Astronomical Photography

Total circulation of books, 227; total circulation of periodicals, 457.

CHARLES M. GOOD, *Librarian.*

LONDON CENTRE

Eight regular meetings of the Society were held during the year. Unless otherwise stated, the meetings were held in the Cronyn Memorial Observatory, University of Western Ontario.

January 29—H. R. Kingston: "Resumé of a Visit as Guest of the Franklin Institute, Philadelphia"; Omar Kilburn: "The 1951 Observer's Handbook"; W. G. Graham: "Creation of a Six-inch Reflecting Telescope."

March 16—P. J. Sandiford, M.A.: "What Starlight Can Tell Us"; Mrs. B. M. Johnson: "Constellation Study."

April 20—Visit to the radar station at Clinton. Lunch in the Officers' Mess.

May 19—Visit from the Windsor Centre. Dinner at the University cafeteria. W. G. Mitchell, B.A.I., Henry Lee, B.S.E.E., and Cyril Hallam, B.A.: "The Origin of the Universe."

October 19—R. H. Cole: "The Measurement of Stellar Distances"; G. W. Walden: "Professor J. C. Kapteyn."

November 16—J. F. Heard, Ph.D., David Dunlap Observatory: "Modern Air Navigation." Observations.

December 14—Election of Officers; G. R. Magee: "Exploding Stars"; H. R. Kingston: "An Astronomical Game."

R. E. WINTERS, *Secretary.*

EDMONTON CENTRE

Regular meetings were held in Room 142 of the Arts Building, with refreshments served later in Room 111. For the use of these rooms we are indebted to the University authorities. The December meeting was held

in the King Edward Hotel banquet room, and was preceded by a dinner.

Attendance averaged 36, varying from 28 to 43. This is a little better than last year.

The main papers were as follows:

December—R. L. Rutherford: "The Relation of Astronomy to Geology."
January—Films on Maps and on Atomic Physics.
February—H. Grayson-Smith: "The Creation."
March—S. A. Linstedt: "Planetaria."
April—Parts IV and V and the film on Atomic Physics.
May—W. W. Happ: "Sir Arthur Eddington."
October—J. W. Campbell: "The Conquest of Space."
November—G. S. Lord: "California Telescopes."

The paper by Dr. Grayson-Smith was published in the Society's JOURNAL and doubtless many of our members enjoyed it again after hearing the original talk.

Handbook talks were given regularly by Dr. Campbell. At most meetings Mr. Burt found some matters of general interest to comment on from the Montreal Centre's publication *Skyward*. The library continues to be used fairly regularly. Two new books just added are *Some Famous Stars* and *The Origin of the Earth*, both by W. M. Smart. We continue to subscribe to the popular journal *Sky and Telescope*.

E. S. KEEPING, *Secretary and Librarian.*

CENTRE DE QUÉBEC

L'année astronomique de notre Centre a été marquée par un évènement particulièrement brillant: la célébration du 10e anniversaire de la société, le 18 avril. La principale manifestation été une conférence publique faite à l'Université Laval par M. le Commandant Lucien Beaugé. Le conférencier a émis des idées personnelles sur la cause des marées et a parlé de la température des eaux dans le golfe St-Laurent. A ce propos, il a suggéré qu'on mette a exécution le projet de comblement du détroit de Belle-Isle, en vue d'améliorer les conditions climatériques de toute la région du golfe et d'une partie de la province. Les comptes-rendus de cette conférence parus dans les journaux, ont créé un grand mouvement d'intérêt dans le public, tant au pays même qu'à l'étranger.

La conférence a été suivie d'un vin d'honneur au salon de l'Université. Au dîner qui précédait la réunion, M. le Président avait convié le conférencier et divers invités de marque, parmi lesquels Monsieur le Ministre Bona Dussault, membre honoraire de la société. Nous avions aussi le grand honneur d'avoir parmi nous des représentants du Montreal Centre, dans les personnes de son Président, Miss Isabel Williamson, et de Mr. F. DeKinder.

La réunion générale du 27 juillet a été consacrée à l'élection d'un nouveau Bureau pour l'exercice 1951-52. Puis, nous avons eu, les samedis 13 octobre et 24 novembre, nos réunions mensuelles réservées à l'observation. Ces réunions du samedi, à l'observatoire, ont été très populaires et seront sans doute continuées à l'avenir. La réunion annuelle d'aujourd-hui, 10 janvier 1952, convoquée pour l'adoption des rapports de l'année, qui devait avoir lieu en décembre, a dû être retardée d'un mois à cause de l'édition de *Notre univers merveilleux*, qu'a entreprise elle-même la société. Aux dernières nouvelles, le volume devrait paraître dans la dernière semaine de janvier.

Toutes les occultations observables à Québec, au cours de l'été et de l'automne, ont été calculées par M. Jacques Sauvé. Une seule, sux dix environ, a pu être observée.

L'observatoire a été ouvert au public comme d'habitude durant les mois d'été. Nous avons accueilli près de mille visiteurs, soit sensiblement le même nombre que l'an dernier.

Nos chroniques hebdomadaires dans les journaux se sont continuées sans interruption, et nous avons encore distribué le Graphique du Ciel, grâce à la générosité de la Maryland Academy of Sciences, qui nous a fait parvenir 3000 copies de ce précieux instrument de propagande.

PAUL-H. NADEAU, *Secrétaire.*

WINDSOR CENTRE

The Windsor Centre has held eight public meetings in Windsor, one joint meeting with London Centre at London, Ontario, and two council meetings. The public meetings were held in the Art Gallery of The Willistead Library through the courtesy of the Chief Librarian, Miss A. Hume. The June meeting and the September council meeting were held at the home of Mr. D. C. Bawtenheimer. The January council meeting was held at the home of the President, Mr. R. G. Warwick.

The public meetings are announced in the local daily paper and a card is sent to each member shortly before each meeting. The average attendance at the public meetings was thirty-nine.

The main topics given at the public meetings are as follows:

January 16—A. E. Johns, Ph.D.: "Order Is Heaven's First Law."

February 20—F./Lt. K. R. Greenaway: "Polar Navigation."

March 20—Students' Night conducted by D. C. Bawtenheimer, W. G. Mitchell, B.A.I., and Cyril Hallam, B.A.

April 17—Dr. E. R. Phelps: "Television in Schools."

May 19—Joint meeting at London, W. G. Mitchell, B.A.I., Henry Lee, B.S.E.E., and Cyril Hallam, B.A.: "The Origin of the Universe."

June 19—R. G. Warwick, B.A.: Motion pictures in colour of "Life in the Andes" and "The Gaspé Peninsula."

September 18—Cyril Hallam, B.A.: "An Introduction to the Heavens," followed by motion pictures of solar prominences, and R. G. Warwick, B.A.: "The Main Constellations."
October 18—Lee F. McGee, B.A.: "Man and Science."
November 20—Judge J. J. Coughlin: "Questions and Answers."

Centre français de Montréal

Le siège du Centre français de Montréal est demeuré à l'Ecole Polytechnique où la société bénéficie de multiples avantages qu'elle doit au directeur actuel de l'école, monsieur Ignace Brouillet.

Le conseil s'est réuni quatre fois pour discuter des affaires de la société et de notre centre en particulier.

Le président a convoqué les membres onze fois en séance générale. Voici la liste de ces séances et les sujets qui y ont été traités, tant par les adhérents que par des conférenciers invités.

31 janvier—Rév. Frère Robert, f.e.c.: "Les Céphéides."
14 février—F. DeKinder: "Quand un astronome amateur regarde le Soleil."
28 février—Jacques Lenoir: "La genèse de la Terre."
14 mars—Trois films sur l'astronomie, avec commentaires de DeLisle Garneau.
28 mars—Jean Asselin: "Cyrano dans la Lune."
11 avril—DeLisle Garneau: "Dans les Sphères étoilées."
25 avril—J. A. Buteau: "Visites aux grands observatoires américains."
9 mai—Rév. Frère Robert, f.e.c.:"Propos astronomiques."
17 octobre—Election des officiers et films sur l'astronomie.
7 novembre—René Robert: "Le Spectroscope"; DeLisle Garneau: "Soleil."
5 décembre—Rév. Frère Robert, f.e.c.: "De la pluralité des mondes et de Fontenelle"; DeLisle Garneau: "Les planètes moyennes."

Pour la première année depuis la fondation du centre français des séances d'observation ont donné une place importante dans les travaux de notre centre. M. DeLisle Garneau a reçu à son observatoire, rue Wilson, à 13 séances d'observation, tous les membres qui veulent s'initier aux principaux objets célestes et apprendre la technique de l'observation.

Le 7 décembre, Radio-Canada présentait aux "actualités du jour," un rappel de la fondation de l'observatoire "Ville-Marie" le 7 décembre 1941.

F. Laforest, *Secrétaire-Trésorier.*

FINANCIAL STATEMENT, 1951

I. NATIONAL TREASURER

GENERAL ACCOUNT

RECEIPTS		
Balance December 31, 1950		$ 120.18
Grants received—Canada	$2,000.00	
Ontario	500.00	
Fees from Centres	2,870.00	
Fees from general members	1,448.60	
Subscriptions to Journal	467.54	
Sale of Observer's Handbooks	847.34	
Sale of publications (reprints, etc.)	1,206.62	
Advertising	168.47	
Premiums and exchange (net)	34.93	
Interest (Life Members Bonds)	53.63	9,597.13
		$9,717.31
DISBURSEMENTS		
Publications	$5,748.14	
Grants to Centres	1,129.00	
Salaries	1,399.90	
Rent and Light	495.08	
Office expenses (stamps, etc.)	302.00	
Office printing	287.62	
Stencils	18.53	
Annual At-Home	192.45	
General expense	94.20	9,666.92
General account balance		$ 50.39

LIFE MEMBERSHIP FUND

Bank balance December 31, 1950	$ 66.16	
Receipts		
(2) Life Members' fees	80.00	
Bank balance December 31, 1951		$ 146.16

BUILDING FUND

Bank balance December 31, 1950	$ 645.00	
Receipts		
Interest	196.56	
D. of C. bond called, H076124	50.25	
Bank balance December 31, 1951		$ 891.81

SOUTHAM PRESS FUND

Bank balance December 31, 1950	$ 336.98	
Receipts		
Interest	55.37	
Bond called, D. of C., A136139	100.50	$ 492.85
Disbursements		
Bank charges re bonds, safekeeping and renewal	14.00	
Medal	12.00	26.00
		$ 466.85

BONDS AND DEBENTURES HELD BY R.A.S.C. AT IMPERIAL BANK

Account	*Brought Fwd.*	*Called*	*Carried Fwd.*	*Yrly. Int.*
Life Members Fund	$ 1,800.00		$ 1,800.00	$ 53.63
Building Fund	6,700.00	$ 50.00	6,650.00	196.56
Southam Press Fund	1,950.00	100.00	1,850.00	55.37
Totals	$10,450.00	$150.00	$10,300.00	$305.56

J. H. Horning, *National Treasurer.*

II. REPORTS OF TREASURERS OF CENTRES

TORONTO CENTRE

Receipts		Disbursements	
Balance from previous year	$385.89	Rentals	$ 34.85
Grant from National Council	338.00	Expenses re meetings	122.53
		Postage and printing	93.66
		Miscellaneous	30.50
		Balance carried forward	442.35
Totals	$723.89		$723.89

Special Purpose Account

Receipts		Disbursements	
Balance from previous year	$586.18	Insurance on equipment at C.N.E.	$ 9.00
Fee for astronomical services at C.N.E.	150.00	Express on equipment	6.30
		Repairs on telescope	5.00
		Balance carried forward	715.88
Totals	$736.18		$736.18

T. H. Mason, *Treasurer.*

OTTAWA CENTRE

Receipts		Disbursements	
Balance from previous year	$ 45.83	Fees to National Treasurer	$192.00
Members' fees	192.00	Stationery	.85
Grant from National Council	87.00	Postage	21.51
Donations	10.00	Printing	9.46
Bank interest	.50	Expenses re meetings	160.93
Sale of 1950 Handbooks	.21	Exchange on cheques, etc.	.77
Sale of 1951 Handbooks	29.60	Cost of 1952 Handbooks	16.00
Proceeds of Annual Dinner	126.00		
			$401.52
		Balance carried forward	89.62
Totals	$491.14		$491.14

S. A. Mott, *Treasurer.*

HAMILTON CENTRE

Receipts		Disbursements	
Balance from previous year	$139.78	Rent	$ 40.00
Members' fees	169.00	Fees to National Treasurer	199.00
Grant from National Council	51.00	Stationery	5.00
Donations	1.30	Postage	16.00
Field night	191.35	Printing	35.35
Sale of books	14.35	Expense re meetings	62.25
Bank interest	.49	Exchange on cheques	.54
		Dr. Hogg Scholarship	60.00
		McMaster Journal	26.80
		Handbooks	4.04
		Balance carried forward	118.29
Totals	$567.27		$567.27

George Murchie, *Treasurer.*

WINNIPEG CENTRE

Receipts		Disbursements	
Balance from previous year	$141.06	Fees to National Treasurer	$ 78.00
Members' fees	60.00	Expense re meetings	12.00
Grant from National Council	34.00		
Donations	1.00		
Bank interest	.68	Balance carried forward	146.74
Totals	$236.74		$236.74

Margaret E. Watterson, *Treasurer.*

VICTORIA CENTRE

Receipts		Disbursements	
Balance from previous year	$400.43	Rent	$ 39.50
Members' fees	178.50	Fees to National Treasurer	241.65
Grant from National Council	79.00	Stationery	5.00
Donations and sundries	178.56	Postage	8.36
Summer course	93.00	Printing	27.80
		Expense re meetings	200.70
		Exchange on cheques	.18
		Miscellaneous	12.84
		F. S. Hogg Memorial Scholarship Fund	125.15
		Balance carried forward	268.31
Totals	$929.49		$929.49

Number of Junior Members included in this report: three.

John L. D. Jervis, *Treasurer.*

MONTREAL CENTRE

Receipts		Disbursements	
Balance from 1950	$205.78	Fees to National Treasurer	$657.00
Members' fees	657.00	Stationery	42.22
Donations		Postage	83.00
Library	13.00	Library	47.04
Equipment	3.00	Rent	82.00
General Fund	189.60	Expenses re meetings	88.94
Grant from National Council	248.00	Equipment	33.53
Bank interest	3.15	Exchange on cheques	1.61
Re-sale of books	28.00	Insurance on equipment	32.35
Members' subscriptions to Frank S. Hogg Memorial Scholarship	12.00	Dues—Greater Montreal Film Council	10.00
		Books bought for re-sale	28.00
		Expenses re Star Night	28.55
		Frank S. Hogg Memorial Scholarship (incl. $12.00 donated by members)	62.00
		Miscellaneous	3.00
		Balance carried forward	160.29
	$1,359.53		$1,359.53

C. N. S. Yarnell, *Treasurer.*

LONDON CENTRE

Receipts		Disbursements	
Balance from previous year	$ 99.22	Fees to National Treasurer	$96.00
Members' fees	51.00	Postage	2.00
Grant from National Council	36.00	Printing	13.24
Bank interest	.58	Expense re meetings	20.00
Collection re dinner	62.00	Exchange on cheques	.41
		Miscellaneous	10.00
		G. A. Bullas of the Cafeteria	60.00
		Balance carried forward	47.15
Totals	$248.80		$248.80

R. E. Winters, *Treasurer.*

VANCOUVER CENTRE

Receipts		Disbursements	
Balance from previous year	$ 24.14	Fees to National Treasurer	91.00
Members' fees	91.00	Postage	4.00
Grant from National Council	43.00	Expense re meetings	10.00
Bank interest	.34	Exchange on cheques	.15
One member paid Nat. Treasurer	3.00	One member paid Nat. Treasurer	3.00
		Balance carried forward	53.33
Totals	$161.48		$161.48

Caroline A. Rogers, *Treasurer.*

EDMONTON CENTRE

Receipts		Disbursements	
Balance from 1950	$ 83.77	Secretary's expenses	$ 10.00
Members' fees	156.00	Fees to National Treasurer	156.00
Associate fee	.75	Treasurer's expenses	2.75
Grant from National Council	48.85	Printing	2.18
Interest	1.28	Expense re meetings	20.02
		Books	10.10
		Balance carried forward	89.60
Totals	$290.65		$290.65

Number of Associate Members included in this report: one.

A. M. P. Smith, *Treasurer.*

QUEBEC CENTRE

Receipts		Disbursements	
Balance from previous year	$ 5.16	Fees to National Treasurer	$204.00
Members' fees	204.00	Postage	87.70
Grant from National Council	56.00	Observatory	163.07
Grant from Prov. Gov., 1950-51	300.00	Administration	100.42
Grant from Prov. Gov., 1951-52	300.00	Exchange on cheques	1.65
Donations	32.06	Miscellaneous	128.92
Bank interest	.68	Balance carried forward	212.14
Totals	$897.90		$897.90

PAUL-H. NADEAU, *Treasurer.*

WINDSOR CENTRE

Receipts		Disbursements	
Balance from previous year	$ 1.07	Fees to National Treasurer	$117.00
Members' fees	111.00	Stationery	9.45
Grant from National Council	43.00	Postage	4.58
Interest	.12	Expenses re meetings	16.00
Premium on U.S. funds	.59	Exchange on cheques	.15
Sale of literature	.40	Miscellaneous	3.00
Miscellaneous	.75	Balance carried forward	6.75
Totals	$156.93		$156.93

W. J. PERSON, *Treasurer.*

SASKATOON CENTRE

Receipts		Disbursements	
Balance from previous year	$34.52	Fees to General Treasurer	$47.00
Members' fees	47.00	Stationery and postage	5.25
Grant from National Council	7.00	Exchange on cheques	.15
Bank interest	.24	Balance carried forward	36.36
	$88.76		$88.76

Number of Junior Members included in this report: one.

R. E. JENSEN, *Treasurer.*

CENTRE FRANÇAIS DE MONTRÉAL

Receipts		Disbursements	
Balance from previous year	$ 42.54	Fees to National Treasurer	$121.50
Members' fees	121.50	Stationery	5.60
Grant from National Council	42.00	Postage	9.35
Donations	10.75	Expense re meetings	28.00
Interest on sale of books	2.70	Miscellaneous	22.20
		Balance carried forward	32.84
Totals	$219.49		$219.49

F. LAFOREST, *Treasurer.*

The Royal Astronomical Society of Canada

OFFICERS FOR 1952

NATIONAL OFFICERS AND COUNCIL

Honorary President—The Honourable W. J. Dunlop, Minister of Education for the Province of Ontario.
President—C. S. Beals, Ph.D., Ottawa.
First Vice-President—J. F. Heard, Ph.D., Toronto.
Second Vice-President—DeLisle Garneau, Montreal.
National Secretary—E. J. A. Kennedy, 3 Willcocks Street, Toronto.
National Treasurer—J. H. Horning, 3 Willcocks Street, Toronto.
Recorder—Frederic L. Troyer, Toronto.
Librarian—D. W. Best, D.D., Toronto.
Council—Charles A. Bell, B.A., Windsor; A. M. Crooker, Ph.D., Vancouver; Balfour W. Currie, Saskatoon; Charles A. Giroux, Quebec; Edgar Guimont, Montréal; G. Harper Hall, Montreal; E. S. Keeping, M.A., Edmonton; Rev. E. F. Maunsell, M.A., Hamilton; R. C. Moffatt, Guelph; Raymond E. Pearce, Toronto; E. H. Pope, Victoria, P. H. Serson, Ph.D., Ottawa; J. A. White, Winnipeg; R. E. Winters, London.

TORONTO CENTRE

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President—F. L. Troyer
First Vice-President—R. E. Williamson, Ph.D.
Second Vice-President—Raymond Pearce
Secretary—John Galt, 43 Adelaide St. E., Toronto.
Treasurer—T. H. Mason
Recorder—Miss Barbara Creeper
Council—C. A. Crook; David Gerrie; E. V. Greenwood; Mrs. K. M. Heaton; Helen S. Hogg, Ph.D.. W. R. Hossack; A. Milne; A. Lloyd Morgan, M.D.; W. R. Sherrick; and *Past Presidents*—E. J. A. Kennedy; J. R. Collins; S. C. Brown; D. W. Best, D.D.; Miss Ruth J. Northcott, M.A.; J. F. Heard, Ph.D.; A. R. Clute, Q.C.

OTTAWA CENTRE

Honorary President—R. M. Stewart
President—D. A. MacLulich
First Vice-President—W. S. McClenahan
Second Vice-President—D. W. R. McKinley
Secretary—R. W. Tanner, Dominion Observatory, Ottawa.
Treasurer—Stanley Mott
Council—A. E. Covington; C. M. Cress; J. L. Locke; F. W. Matley; Miss Ethel D. Steacy.

HAMILTON CENTRE

Honorary President—W. T. Goddard, B.S.E.E.
President—W. J. McCallion, M.A.
Vice-President—O. J. Paton
Curator—G. E. Campbell, M.A.
Secretary-Treasurer—George Murchie, 77 Fennel Avenue West, Hamilton.
Council—H. B. Fox; W. Jack; A. E. Johns, Ph.D., M. W. Johns, Ph.D.; L. O. Jones; Rev. E. F. Maunsell; W. S. Mallory, M.A.; T. M. Norton; F. Schneider; F. Sisman; J. H. Sled, Phm.B.; W. J. Sled, B.A.; W. D. Stewart, B.A.; L. W. Welbourn; B. Wishart.

WINNIPEG CENTRE

Honorary President—L. T. S. Norris-Elye
President—D. R. P. Coats
Vice-President—Miss O. A. Armstrong
Treasurer—Miss M. E. Watterson
Secretary—
Council—Clarence L. Card; Allan Hill; V. Jones; H. E. Rasmussen; Fred Shanks; D. E. Sweeney.

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President—Mrs. J. R. Noble
First Vice-President—Robert S. Evans
Second Vice-President—Edward H. Pope
Secretary-Treasurer—John L. D. Jervis, 1870 Cedarhill Crossroad, Victoria.
Recorder—Major E. R. Gibson
Director of Telescopes—Robert Peters
Council—S. H. Draper; D. P. McAlpine; N. G. Rogers; O. W. Smith; Miss Anne B. Underhill, Ph.D.; F. R. Williams.

MONTREAL CENTRE

Honorary President—G. Harper Hall
President—Miss I. K. Williamson
Honorary Vice-President—A. Norman Shaw, Ph.D.
Vice-President—D. E. Douglas, Ph.D.
Secretary—Henry F. Hall, 1441 Drummond Street, Montreal.
Recorder—E. E. Bridgen
Treasurer—C. N. S. Yarnell
Librarian—C. M. Good
Director of Observations—F. De Kinder
Council—Wm. H. Birtles; W. E. Leeson; Anna I. MacPherson, Ph.D.; A. R. McLennan; T. O. Plant; Paul Scott; R. O. Stevenson; R. Venor; W. J. Yorgan; Mrs. D. Zorgo and *Past President*—J. W. Duffie.

LONDON CENTRE

Honorary President—H. R. Kingston, Ph.D.
President—George W. Walden
Vice-President—W. G. Colgrove
Secretary-Treasurer—G. R. Magee, Ph.D.
Council—R. H. Cole, Ph.D.; E. Fanning; W. Gordon Graham; Omar Kilburn; E. E. O'Connor; and *Past President*—Albert Emsley.

VANCOUVER CENTRE

Honorary President—G. M. SHRUM, PH.D.
President—CARL JORGENSON*
Vice-President—A. OUTRAM
Treasurer—C. A. ROGERS
Secretary—R. J. CLARK, PH.D., 1988 Western Parkway, Vancouver 8.
Recorder—J. S. LAURIE
Public Relations—EILEEN LAURIE
Council—A. M. CROOKER, PH.D.; C. W. DEANS; DEAN W. H. GAGE; CAPT. C. A. MCDONALD; E. M. PRICE; T. SPENCE.

*Deceased

EDMONTON CENTRE

Honorary President—J. W. CAMPBELL, PH.D.
President—E. PHIBBS
Vice-President—H. M. BURT
Treasurer—H. J. MONTGOMERY
Secretary—E. H. GOWAN, PH.D., University of Alberta, Edmonton.
Librarian—E. S. KEEPING (*Acting Secretary*)
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REVIEW OF PUBLICATIONS

X-ray Calibration of Radiation Survey Meters, Pocket Chambers, and Dosimeters, by Frank H. Day (National Bureau of Standards Circular 507). Pages 11; 7¾ × 9¼ inches. Paper bound. Washington, United States Printing Office, 1951. Price 15 cents.

With the increase of the applications of nuclear physics in engineering and medicine, has come a need for simple, easily operated, and moderately accurate instruments to measure the intensity of nuclear radiation. A number of types are available commercially, and the National Bureau of Standards has contracted with two United States Government agencies, the Atomic Energy Commission and the National Military Establishment, to test and calibrate them. The results of tests on instruments available up to 1948 are contained in the present report. R.E.W.

Photography in Astronomy, by E. W. H. Selwyn. Pages 112; 6 × 8½ inches. Rochester, Eastman Kodak Company, 1950. Price $2.75.

The author of this book has provided a sound introduction to the problems and practice of astronomical photography. Recommended references are included for further study of important phenomena not fully covered in a book of this size.

The reviewer feels that careful attention to the chapters on processing will be amply rewarding. It has been my experience that some workers adopt a somewhat frivolous attitude toward this important feature of photography. The book is well illustrated with diagrams and photographs. It is limited, however, in dealing with Kodak photographic materials only.

G. F. LONGWORTH

Der Sternenhimmel, 1952. Pages 102; 5¾ × 8¼ inches. Published by H. R. Sauerlander and Co., Aarau, Switzerland. (Obtainable through Mr. Albert J. Phiebig, 545 Fifth Ave., New York 17, N.Y.)

This yearbook is published under the auspices of the Swiss Astronomical Society, and presents the astronomical phenomena for the year much as in our OBSERVER'S HANDBOOK. Robert A. Naef is the editor of it and also the journal *Orion.*

Phenomena in the sky are given month by month together with six horizon maps. Diagrams are given for the eclipses and occultations which are visible throughout the year. Ephemerides of the sun, moon, planets and bright asteroids near opposition are tabulated, as well as information about interesting double stars, variable stars and nebulae.

A list of thirty observatories in Switzerland shows how active this country is in the field of astronomy. R.J.N.

METEOR NEWS

By Peter M. Millman, *Dominion Observatory, Ottawa*

A Size Classification of Meteoritic Material Encountered by the Earth*

A number of recent papers in meteoric astronomy and allied fields have enabled us to form a much more consistent overall picture of the general nature of the meteoritic material which the earth encounters daily. I would like to summarize some of these results here. Although space forbids more than the briefest mention of each piece of research, I hope that the accompanying list of references will enable anyone interested to follow the matter in more detail.

One of the greatest revolutions in our thinking has occurred in a new realization of the numbers and importance of the very small particles. Preliminary results[1] from a Swedish deep-sea expedition have yielded a surprising quantity of nickel-oxide in cores taken from the ocean bottom. Pettersson and Rotschi conclude that this is chiefly of extra-terrestrial origin and represents an accumulation by the earth of several thousand tons of meteoritic material a day. Opik[2] has discussed, at some length, the implications of this result.

An important paper by van de Hulst[3] dealing with the zodiacal light and the solar corona estimates the space density due to dust particles up to 0.025 inches diameter in the neighbourhood of the earth as 5×10^{-21} gm./cc. (density of material assumed 5). This would mean an accumulation by the earth of 1800 tons of dust a day if it is assumed that the earth sweeps it up at a relative speed corresponding to its motion round the sun, 30 km./sec.; or of 2700 tons a day if the relative speed is 45 km./sec., the approximate average observed velocity of 11,000 faint meteors measured by McKinley[4] with radio equipment.

Further evidence of the arrival of small meteoric particles is found in the collections of nickel-iron dust made from many isolated locations, including the Canadian Arctic.[5,6] Buddhue[7] has published a very complete review of all the previous work on meteoritic dust and has noted a number of cases where this was collected immediately after a meteor shower or bright fireball.

As early as 1937 Opik[8] pointed out that very small meteoritic particles would radiate the heat energy resulting from the collision with the air molecules so rapidly that they would not be heated enough for vaporization. More recently Whipple[9] has extended this theory and has termed these objects micro-meteorites. Their diameters will in general lie in the

*A portion of a lecture before a combined meeting of the Royal Canadian Institute and the Royal Astronomical Society of Canada at Toronto, March 8, 1952.

range 0.001 to 0.0001 inch theoretically. Collections of nickel-iron dust confirm these sizes including the interesting transition stage where the particle is melted on the surface but not vaporized and a small spherule results.

Further confirmation of the existence of micro-meteorites in fairly large numbers is found in the high frequency sounds recorded in V2 rockets,[10] and in the microscopic pittings reported by R. Burnight on exposed polished metal surfaces mounted on V2 rockets. Whipple has pointed out that these rocket results are not inconsistent with the conclusion already reached that finely divided meteoritic material is present in our atmosphere in much larger quantities than previously supposed.

It is of interest to estimate the amount of meteoritic material of various sizes which falls on the earth daily. As a first approximation we can accept Watson's estimate[11] of about half a ton a day in the form of meteorites. Using the visual observations made at the Dominion Observatory over the last five years I find total daily numbers of visual meteors for the whole world very similar to those published by Watson in 1937.[12] Whipple considers 1.25 grams the best value to use for a zero magnitude meteor in the zenith with velocity 40 km./sec. Using this as a starting point and summing all meteors from magnitude -10 to $+10$ we get a very approximate value of about two tons a day added to the earth's mass. It should be noted that, though this result is not far from that found by Watson[11] from the table† on page 115 of his book, it is arrived at from different figures for both masses and numbers of meteors. As already noted there is evidence that several thousand tons of mass a day results from the fall of particles which will in general be less than 0.025 inches in diameter and fainter than magnitude 10.

A very striking conclusion concerning the densities of the bright visual meteors was announced by Whipple in a paper presented at the A.A.S. meeting in December 1951.[13] He has compared upper air densities determined from rockets with those derived from meteor observations and concludes that the meteoroids producing normal meteors have densities in the range from 0.2 to 1.0 that of water. In other words they appear to be porous, fragile structures, typical debris of the Whipple comet model that is assumed to contain large percentages of ices. It is of interest that photographic evidence shows[14] that the Giacobinid shower, which is believed to be one of the most recently formed, consists of particles of unusually "soft" material. We thus find a physical difference between the material of planetary origin that falls as meteorites, and that of cometary origin that appears as meteor showers and sporadic

†Since several authors have used this table it should be pointed out that there seems to be an inconsistency by a factor of ten between the last column and the preceding columns.

visual meteors. It may be mentioned that there is no certain case of a shower meteor falling as a meteorite, and Wylie[15] has called attention to the difference between the typical meteorite orbits, which resemble those of unusual asteroids, and the meteor shower orbits, which are like those of comets.

We can now attempt a very rough general size classification of meteoritic material. This is given in the accompanying table. It must be remembered that the classes will overlap considerably and that the table is open at both ends. The origin of the finest dust is still obscure, but since it is distributed along the ecliptic it is highly probable that the origin of most of it is somehow tied to that of the solar system itself. A small interstellar component may also be present but has not yet been definitely proved by accurate velocity measurements.

SPACE DUST
(encountered by the earth)

Diameter before entering the atmosphere	Type	Daily accretion of mass	Origin
inches		tons	
1000 – 100	crater producing meteoroids	<1	planetary (density high)
100 – 10	meteorites		
10 – 1	fireballs	1 – 10	cometary (density low for larger particles)
1 – .1	normal visual meteors		
.1 – .01	faint radio meteors telescopic meteors		
.01 – .001	faintest telescopic meteors	1000 – 10,000	ecliptic (density high)
.001 – .0001	micro-meteorites		
.0001 – .00001	zodiacal dust		

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MEETINGS OF THE SOCIETY

AT WINNIPEG

November 14, 1951—The regular meeting of the Society was held in the Grain Exchange Building at 8.00 p.m., with the President, Mr. E. R. Gardner, occupying the chair. Eighteen members and guests were present. Mr. Gardner informed the meeting that architects will be submitting plans for a planetarium. He said that the project would be on a scale suitable for this city. Mr. Norris-Elye stated that the meteorite exhibit at the Regina Exhibition had created a great deal of interest.

The Chairman then introduced V. C. Jones, who spoke on "Problems being studied with the 200-inch telescope." Mr. Jones commented on his visit to Palomar. With the aid of slides, he further presented information of the spectographic red shifts. Slides were shown of other galaxies and particular mention was made of how these photographs were obtained. It was stated that windows or holes were found in our own universe through which investigation of other galaxies had been possible. He showed the spiral motion indicated by the photographs of other systems and then stated that our sun also revolves within its own galaxy. He further intimated that complete revolution of our solar system in the Milky Way had about the same duration as the ice ages on our earth.

V. MARTENS, *Recorder pro tem.*

January 17, 1952—The regular meeting of the Society was held in the Grain Exchange Building at 8.30 p.m. Mr. D. R. P. Coats, our president for 1952, acted as Chairman. Fifteen members and guests attended the meeting.

Mr. V. Martens was elected recording secretary, and Miss Watterson added the duties of corresponding secretary to the treasurer's office.

The Society felt indebted to Mr. A. J. Vincent for his meticulous service as secretary for the past year and it was requested that Miss Watterson convey an expression of thanks to him in letter form.

The members were reminded that the Society has certain equipment such as telescopes, books and lantern slides which are scattered throughout the membership. Mr. Coats expressed the wish that good use be made of this equipment and hoped that at some time we would find a central location for it.

The Society is grateful for the very convenient lecture room where it can hold its regular meetings. Miss Watterson was asked to thank the secretary of the Grain Exchange for the courtesy extended to us.

The main item of interest for the evening was the short talk by our President on the subject of "Photographing the Moon and Sun." He read passages from old literature where workers expressed the difficulty in taking these pictures and even stated that the light of the moon did not affect their photographic plates. These of course were the days before high sensitivity films were available.

The first photographs of the moon were taken in 1840 by the Daguerreotype process. Mr. Coats illustrated his remarks with two 11 x 14 inch photographs of the moon taken in 1865 and in 1873. The members were especially impressed with the clarity and the detail obtained at that early date. The eclipse and the phases of the moon were also taken in 1865. Some time later the planets were photographed of which Jupiter was the first.

Mr. Coats showed one of his photographs taken with his own equipment.

Further discussion on the photographing of the sun followed. It was stated that amateurs would encounter great difficulties in photographing the sun. Mr. Gardiner gave details of photographing the sun through the spectroheliograph.

The subjects of telescope making and observatory location were discussed. The President stated that he would approach the school board about the use of the towers at either St. Johns or Kelvin High School for this purpose.

V. MARTENS, *Recording Secretary.*

AT SASKATOON

January 22, 1951—The meeting was opened by the President. An address was given by Prof. F. H. Edmunds on "Exploration for Oil." Prof. Edmunds explained the necessity of exploration for oil since planning depends on the known reserves of oil. He then went on to discuss the methods of exploration. In the early days seepages of gas and oil were used as a basis for drilling. Later on it was observed that oil occurred to a large extent in anticlinal structures and, as a result, large surveys were made to locate anticlinal structures which would then be drilled. Finally various geophysical methods came into use. These methods are of three types: magnetometer surveys, gravity meter surveys and seismic surveys. Prof. Edmunds discussed these three methods and their accuracy in locating oil. He also mentioned a recent geochemical method of exploration. The address was illustrated with a number of slides which illustrated drilling and exploration methods and also the geological structure of the prairie regions.

February 8, 9, 10, 1951—No regular meeting was held during February. Instead the Saskatoon Centre arranged a display in the Physics Open House, held by the Physics Club of the University. Messrs. Beesling, Ketchum and Miles displayed telescopes which they had built. They also demonstrated the procedure of making amateur telescopes. Several large photographs of astronomical objects were also exhibited. Mr. Small had an exhibit of several spectroscopes and gaseous discharge tubes. A notebook was left open, so those interested in astronomy or telescope making could leave their names and addresses. Nearly 100 people left their names in this book.

March 13, 1951—Mr. Small opened the meeting and outlined the purposes of the Society. A report on the financial condition of the centre was then given by the treasurer.

The President outlined briefly a proposed telescope making club and Mr. Ketchum outlined the procedure of making a mirror for a telescope. It was moved by Mr. Erwin, seconded by Mr. Martin that a vote of thanks be given to Messrs. Ketchum, Miles and Beerling for their part at the Physics Show. The motion was carried unanimously.

The President introduced Mr. J. G. V. Taylor, a graduate physics student of the University of Saskatchewan, who gave an address on "Variable Stars."

Mr. Taylor discussed what variable stars are and how they are studied. He emphasized that amateur astronomers have been a great help to professional astronomers by carrying out observations of variable stars.

Then he described the various types of variables and the theories forwarded to explain their variability. The types discussed were eclipsing binaries, long period variables, cepheid variables, irregular variables, novae and super-novae. Examples of the various types were given and the importance of the variable stars was mentioned.

The possibility of holding summer meetings and the problems associated with such meetings was brought up and discussed, but no definite decisions were made.

September 21, 1951—A closed meeting, for members only, was held on September 21. This was an informal meeting to discuss the future course of the Saskatoon Centre. The possibility of continuing with the small membership we then had was examined. It was decided to temporarily suspend activities until the New Year and then hold a meeting to decide the fate of the Saskatoon Centre.

R. E. JENSEN, *Secretary-Treasurer.*

AT VICTORIA

Report on the Summer Course

During August 1951 the Victoria Centre of the Royal Astronomical Society gave its 20th annual summer course of lectures entitled "Summer Evenings with the Stars." This series of lectures is designed to introduce the general public to astronomy, and each clear evening after the lecture members of the Society assisted in showing the heavens to those interested. This year Miss Jean K. McDonald spoke on "Signposts to the Stars," K. O. Wright spoke on "The Earth in the Universe," F. T. Naish spoke on "The Solar System," and E. R. Gibson discussed "Mountaineering on the Moon."

The climax of the course was a visit to the Dominion Astrophysical Observatory, where by the courtesy of the Director, Dr. R. M. Petrie, the 72-inch telescope was, for that evening, to be devoted to showing some of the wonders of the sky. However, man proposes and the weather disposes! Although the four preceding Monday evenings had been clear and astronomically delightful, late on the afternoon of the day for the visit to the Observatory there was a sharp thunderstorm, and the heavens opened. In spite of this, some 50 people braved the downpour and upon their arrival at the Observatory were greeted by clearing skies. Unfortunately, although a few lights were on, there was not sufficient electric power to motivate the motors that moved the telescope and dome, so nothing could be observed. After the Observatory staff had graciously explained the working of the telescope and other instruments, coffee and biscuits were served, thus bringing to an end the 20th annual summer course.

This year there was a record-breaking attendance of 183 at the course, and from the proceeds of the course, the Victoria Centre was able to contribute the sum of $100.00 to the Frank S. Hogg Memorial Fund.

AT OTTAWA

December 7, 1950—The annual dinner meeting of the Centre was held in the Experimental Farm Cafeteria. A brief business meeting to hear the results of balloting for officers was followed by the address of the retiring president, Dr. Peter M. Millman of the Dominion Observatory, who spoke on "Space Travel." The main requirements for an operational space-ship were outlined; the difficulties were of a kind that can be overcome by a great industrial effort. The step-rocket solution was discussed; then, with the aid of numerous photographs and drawings, Dr. Millman took his audience on a space tour in such a rocket. First port of call was the moon, then Venus, Mercury, Mars, Jupiter, and Saturn. The trip thus gave a good review of the astronomy of the solar system.

January 9, 1951—A joint meeting of the Centre with the Canadian Geographical Society heard Dr. V. B. Meen, director of the Royal Ontario Museum of Geology, speak on "The Great Meteor Crater in Ungava." The visit of his party to the crater in the summer of 1950 was described, and illustrated with motion pictures. The evidence for its meteoritic origin was explained, and its size compared with that of other craters on the earth and moon. The need for further study was emphasized. A large audience, including the Governor-General, followed his account with interest. In thanking the speaker, James Hargreaves, president of the Ottawa Centre, urged that the crater be recognized as a scientific reserve, and every provision made for its adequate study.

R. W. Tanner, *Secretary.*

AT MONTREAL

February 22, 1951.—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, February 22, 1951, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. The meeting was attended by 77 members and visitors. The Librarian, Mr. Good, acknowledged the gift of "Physical Optics" presented to the Library by Mr. Birtles. The Handbook talk followed, "List of Brightest Stars" explained by Mr. Birtles.

The speaker of the evening, Mrs. Margaret Mayall, was then introduced. Mrs. Mayall is on the staff of the Harvard College Observatory, and is a well known astronomer and authoress. She has done notable work in the study of "Stellar Spectra", which was the subject presented.

A fine series of slides was shown and interestingly explained. At the conclusion of the lecture, numerous interesting questions were asked, and answered by Mrs. Mayall. The thanks of the Centre were appropriately expressed by Mr. DeKinder.

March 29, 1951.—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, March 8, 1951, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. 70 members and visitors were present.

It was moved by Mr. DeKinder, seconded by Mr. Garneau and carried that the following be admitted to membership in the Society: Messrs. H. Dubrule, P. E. Lafontaine, and Mrs. M. Beardsley of Springfield, Vt.

Attention was drawn to the tribute to Dr. F. S. Hogg published recently, a copy of which is available to members who wish to read it.

Notice of the regular observation meetings held each Saturday evening at Ville Marie Observatory was given, and invitation extended to those interested to participate in observations of the planet Uranus which are being conducted, Mr. Bryan Cockhill being in charge of this programme. The Handbook talk was given by Mr. DeKinder upon the use of the "Sky Month by Month" pages, using that for March as illustration. Mr. DeKinder also drew attention to the possibility of observing the zodiacal light and the gegenschein (counter-glow) during the month.

The subject for the evening "The Neighbouring Stars" was presented in three parts: "The Nature of the Stars" by Dr. D. E. Douglas; "Their distances and motions" by Mr. A. Kneeland; "Unusual Stars" by Mr. C. M. Good. Slides were used to illustrate particular features in these addresses. At the conclusion a question period followed.

March 29, 1591.—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, March 29, 1951, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. 73 members and visitors were present.

A letter from Mrs. H. S. Hogg in acknowledgement of the Centre's message of sympathy, was read by Dean H. F. Hall. The President acknowledged the gift of "Essentials of Astronomy" to the Library, made by Mrs. C. Laberge. The Handbook talk, given by Mr. Bryan Cockhill followed, on the use of pages 60-61 of the Handbook, "Variable Stars".

The speaker of the evening, Dr. D. A. Keys, was then introduced by the President. While at McGill University as Professor of Physics, Dr. Keys was active in the Centre and is well known to us. His subject, "Some Aspects of the Canadian Atomic Energy Project", was illustrated by a series of slides. Commencing with a review of the study of radiation and energy within the

atom, citing the work of Professors Rutherford and Soddy of McGill as of immense importance in the progress made, he gave some explanation of the structure of atoms and isotopes.

Passing on to a brief description of the Chalk River Plant, his slides showed some of the equipment. The speaker discussed the experiments carried on and something of the purposes and discoveries made, including radioactive cobalt, mass 60, germanium, and the production in the laboratory of six new elements not found naturally.

This was followed by some remarks on the production of power by atomic means, and of other benefits to humanity which will follow the application of knowledge gained through atomic research. Canada is taking a very prominent part in this field of work. At the conclusion of his address, Dr. Keys answered a number of interesting questions from the audience. The thanks of the Centre were expressed by Mr. Ross Ford.

April 12, 1951.—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, April 12, 1951, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. 54 members and visitors were present.

A letter from the National Secretary regarding the "Chubb" Meteor Crater in Ungava, and the proposed resolution was read. Dean Hall proposed, Miss A. Ross seconded, that the resolution as presented be sent to the Minister of Lands and Forests of the Province of Quebec. Carried.

A letter from the National Secretary concerning the Frank S. Hogg Memorial Fund to aid students in astronomy, was read and the object of the Fund explained, as was also the action taken by the Council to contribute to the fund. Members were invited to make personal contributions, either direct or through the Treasurer of the Centre.

The President expressed the thanks of the Centre to Dr. D. Douglas for the gift of the slides used in his lecture, to the Centre. These slides form a useful addition to the Centre's collection. Thanks were also tendered to Mr. Earl Milton, who has brought the Centre's "Scrap Book" up to date, for his work in completing this record of activities. On behalf of the Library, the gift by Mr. Glassco of Rosen's "Naming of the Telescope" was also acknowledged. Mr. F. P. Morgan then gave the Handbook talk on "Double Stars" using pages 62-63 of the Handbook for material.

The final lecture of the introductory series was then given by the President, under the title of "Star Cities", in which a description of the galaxy, and some of the nearer external galaxies was given, concluding with references to the Clouds of Galaxies, and to the local group, with data on their distances from us. At the conclusion of the lecture, Miss Williamson answered a number of questions from the audience. The speaker was thanked by Mr. C. Laberge.

April 26, 1951.—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, April 26, 1951. The President, Miss I. K. Williamson, was in the Chair. 82 members and visitors were present. It was reported that in response to the resolution forwarded to the Quebec Minister of Lands and Forests the Centre had been informed that the Government of the Province of Quebec is taking the subject under consideration. In connection with the Frank S. Hogg Fund, the arrangements by which members may contribute through the Centre were again outlined. It was moved by Mr. DeKinder, seconded by Mr. D. Zackon, that Mr. Ian A. Maclaine be admitted to membership. The President reported on a visit to the Quebec Centre on the

occasion of their Tenth Anniversary. In response to the invitation, the President and Mr. DeKinder attended the meeting, and were given a most cordial reception by the Quebec Centre. A most interesting lecture was given by M. Lucien Beauge, after which the visitors were taken to the Centre's observatory located in one of the Martello towers.

The Handbook talk followed, given by Mr. DeKinder, the subject being "Star Clusters, Galactic and Extra-Galactic Nebulae".

The speaker of the evening, Dr. Pierre Demers of the University of Montreal, spoke on the subject of "Cosmic Rays". Opening with a survey of the history of the enquiry into the nature of cosmic rays, Dr. Demers explained the primary and secondary radiation, and the particles associated and stated that protons make up the principal part of cosmic rays, and that the primary radiation originates away from the earth. Cosmic ray primaries must exist everywhere in the universe, and the mass present in the form of cosmic rays is greater than the mass of visible stellar bodies. In the course of the explanations, slides were used, including some of the high altitude stations in the Alps. At the conclusion of the lecture, Dr. Demers dealt with a series of questions from the audience. The thanks of the audience was tendered by Mr. Ross Stevenson.

May 10, 1951.—The meeting was held at Macdonald Physics Building, McGill University, on Thursday, May 10, 1951, at 8.15 p.m. The President, Miss I. K. Williamson, was in the Chair. 57 members and visitors were present.

This meeting being the final one of the 1950-51 season, a special programme was arranged. A series of 25 slides was thrown on the screen, and each member of the audience was asked to identify the subject and record it. The slides were again shown, and the subject named, after which the method of arriving at the "score" was explained, and scores asked for. Mr. R. Venor secured first place, and was awarded the first prize. Three other prizes were given to those who obtained the next highest points.

A social hour followed, during which refreshments were served.

E. E. Bridgen, *Recording Secretary.*

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